TRANSCODING APPARATUS AND METHOD, AND TARGET BIT ALLOCATION AND PICTURE COMPLEXITY ESTIMATION APPARATUS AND METHODS USED FOR THE SAME

BACKGROUND OF THE INVENTION

[01] This application claims priorities from U.S. Patent Application No. 60/430,086, filed on December 2, 2002, in the U.S. Patent and Trademark Office, and from Korean Patent Application No. 2003-8146, filed on February 10, 2003, in the Korean Intellectual Property Office, the disclosures of which are incorporated herein in their entireties by reference.

1. Field of the Invention

[02] The present invention relates to transcoding, and more particularly to picture complexity estimation in transcoding, and target bit-allocation for controlling bit-rate during transcoding.

2. Description of the Related Art

[03] FIG. 1 is a block diagram of an MPEG (Motion Picture Experts Group) encoder.

[04] An MPEG encoder receives images and performs DCT (Discrete Cosine Transformation), quantization, VLC (Variable Length Coding), etc., on

the images and outputs an encoded bitstream. Bit-rate control is necessary so as to make the bit-rate of the encoded bitstream constant. Generally, such bit-rate control is performed by a bit-allocation operation which determines the target number of bits to be allocated to one picture to be encoded, and a quantization value determination operation which determines quantization values on the basis of the target number of allocated bits.

[05] For example, if it is assumed that an input image should be encoded at a bit-rate of 3Mbps, and 30 frames, i.e., 30 pictures per second are provided, 300 kbit are allocated for one picture. This is the result of the bit-allocation operation. Then, quantization is performed. If it is assumed that 300 macroblocks exist in one picture, 1kbit is allocated for one macroblock. Quantization values used for quantization are determined on the basis of the number of allocated bits. If the number of the allocated bits is large, the quantization value should be small. If the number of the allocated bits is small, the quantization value should be large.

[06] Transcoding is a technique for transforming the predetermined bit-rate or size of an image into another bit-rate or size.

[07] FIG. 2 is a block diagram used for describing a transcoding method for bit-rate transformation.

[08] To transform the bit-rate of a bitstream coded according to the MPEG standards, an MPEG decoder 210 and an MPEG encoder 220 are required, as shown in FIG. 2. The MPEG decoder 210 receives a bitstream encoded

according to the MPEG standards and decodes the bitstream, and the MPEG encoder 220 encodes the decoded image at another bit-rate.

[09] FIG. 3 is a block diagram used for describing a transcoding method for both bit-rate and picture size transformation.

[10] To transform picture size as well as bit-rate, a down sampler 330 is further required, as shown in FIG. 3. The down sampler 330 performs sampling of input picture data to reduce the size of the picture. In this transcoding method, an MPEG encoder 320 is provided to perform bit-rate control. For performing the bit-rate control, the MPEG encoder 320 may use a general bit-rate control method. However, it is more efficient for the MPEG encoder 320 to perform bit-rate control using various additional information output from an MPEG decoder 310.

[11] U.S. Published Patent Application No. 2002-080877 has disclosed a technique for transcoding compressed digital video streams. As described in the above application, a transcoding apparatus includes a decoder, an encoder, and an estimator. The estimator estimates complexities of current and previous decoded pictures. The encoder performs bit-allocation for a current picture in order to maintain image quality of the new reconstructed picture. However, the disclosed conventional technique has low efficiency, because it does not use previous encoded picture information.

SUMMARY OF THE INVENTION

[12] The present invention provides a transcoding apparatus and method, and a picture complexity estimation method and apparatus used for the same. During the transcoding process, complexity calculation on each picture is used to perform bit-allocation for controlling bit-rate. The present invention provides a transcoding apparatus and method, and a picture complexity estimation method and apparatus used for the same, which are capable of improving image quality upon transcoding, by efficiently estimating the complexity of each picture using both complexity information of a decoded picture at a previous time and complexity information of an encoded picture at a previous time.

[13] According to an aspect of the present invention, there is provided a transcoding apparatus comprising: a video decoding unit which receives a compressed bitstream and performs decoding thereof to output decoded pictures; a complexity estimation unit which estimates complexity of a current picture among the decoded pictures to encode the current picture; a target bit-allocation unit which performs desired bit-allocation using the complexity information of the current picture; a bit-rate control unit which controls bit-rate using bit-allocation information and state information from memory, which outputs an encoded bitstream; and a video encoding unit which encodes the decoded pictures on the basis of the bit-allocation and state information of the bit-rate control unit.

[14] According to another aspect of the present invention, there is provided a unit for estimating complexities of pictures, the unit comprising: a decoded picture information receiving unit which receives complexity information of decoded previous and current pictures; an encoded picture information receiving unit which receives complexity information of an encoded previous picture; and a complexity estimation unit, which estimates complexity of a picture to be currently encoded, using the complexity of the decoded previous and current pictures and the complexity of the encoded previous picture.

[15] According to still another aspect of the present invention, there is provided a bit-allocation unit comprising: a complexity estimation unit which receives a compressed bitstream, performs decoding thereof, outputs decoded pictures, and estimates complexity of a current picture among the decoded pictures; and a bit-allocation unit which performs desired bit-allocation using the complexity of the current picture.

[16] According to still yet another aspect of the present invention, there is provided a transcoding method comprising: receiving a compressed bitstream and performing decoding thereof to output decoded pictures; estimating complexity of a current picture among the decoded pictures; performing desired bit-allocation using the complexity of the current picture; controlling bit-rate using bit-allocation information and state information from memory, which outputs encoded bitstream; and encoding the decoded pictures on the basis of the bit-allocation and state information.

[17] According to further another aspect of the present invention, there is provided a method for estimating complexities of pictures, the method comprising: receiving complexity information of decoded previous and current pictures; receiving complexity information of an encoded previous picture; and estimating complexity of a current picture to be encoded, using the complexity information of the decoded previous and current pictures and the complexity information of the encoded previous picture.

[18] According to still further another aspect of the present invention, there is provided a bit-allocation method comprising: receiving a compressed bitstream, performing decoding thereof, outputting decoded pictures, and estimating complexity of a current picture among the decoded pictures; and performing desired bit-allocation using complexity of the current picture.

[19] According to still yet further another aspect of the present invention, there is provided a computer readable medium having embodied thereon a computer program for a transcoding method comprising: receiving a compressed bitstream and performing decoding thereof to output decoded pictures; estimating complexity of a current picture among the decoded pictures; performing desired bit-allocation using the complexity of the current picture; controlling bit-rate using bit-allocation information and state information from memory, which outputs an encoded bitstream; and encoding the decoded pictures on the basis of the bit-allocation and state information.

[20] According to more further another aspect of the present invention, there is provided a computer readable medium having embodied thereon a computer program for a picture complexity estimation method comprising: receiving complexity information of decoded previous and current pictures; receiving complexity information of an encoded previous picture; and estimating complexity of a current picture to be encoded, using the complexity information of the decoded previous and current pictures and the complexity information of the encoded previous picture.

[21] According to still more further another aspect of the present invention, there is provided a computer readable medium having embodied thereon a computer program for a bit-allocation method comprising: receiving a compressed bitstream, performing decoding thereof, outputting decoded pictures, and estimating complexity of a current picture among the decoded pictures; and performing desired bit-allocation using complexity of the current picture.

BRIEF DESCRIPTION OF THE DRAWINGS

[22] The above and other features and advantages of the present invention will become more apparent by describing in detail exemplary embodiments thereof with reference to the attached drawings in which:

[23] FIG. 1 is a block diagram of an MPEG (motion picture experts group) encoder;

[24] FIG. 2 is a schematic view used for describing a transcoding method for bit-rate transformation;

[25] FIG. 3 is a block diagram used for describing a transcoding method for both bit-rate and picture size transformation;

[26] FIG. 4 is a diagram showing the structure of a GOP (group of pictures);

[27] FIG. 5 is a block diagram describing a conventional bit-rate control method used in transcoding;

[28] FIG. 6 is a block diagram showing the construction of a transcoding apparatus, according to the present invention;

[29] FIGs. 7A and 7B are graphs showing complexity ratios of encoded previous pictures to decoded previous pictures with respect to picture numbers according to the MPEG standards, respectively;

[30] FIG. 8 is a flow chart illustrating a transcoding method according to the present invention; and

[31] FIGs. 9A through 9C are graphs showing image quality variations with respect to frame numbers comparing a transcoding technique according to the present invention to the conventional technique.

DETAILED DESCRIPTION OF THE INVENTION

[32] Hereinafter, embodiments of the present invention will be described in detail with reference to the appended drawings.

[33] Bit-allocation is required to estimate and pre-allocate the target number of bits required for encoding one picture. For performing bit-allocation, picture complexity should be predetermined using Equation 1 below.

$$X_I = S_I Q_I, \quad X_P = \frac{S_P Q_P}{K_P}, \quad X_B = \frac{S_B Q_B}{K_B} \qquad .... \ (1)$$

[34] Wherein, I, P, and B represent an I picture, a P picture, and a B picture, respectively. Also, X represents picture complexity, S represents the number of bits generated for each picture, Q represents an average quantization value for each picture (i.e., the average quantization value is obtained by averaging quantization values of different macroblocks), and K is a constant representing relative complexity difference among the I picture, P picture, and B picture.

[35] FIG. 4 is a view showing the structure of a GOP (group of pictures).

[36] GOP 400 is a group of successive pictures beginning with an I picture. The I picture is a picture compressed in JPEG (Joint Photographic Coding Experts Group) format, the P picture is a picture subjected to forward estimation, and the B picture is a picture subjected to forward, backward, and interpolation estimations. MPEG (Motion Picture Experts Group) video consists of these three types of pictures arranged with a constant pattern. An I picture can be generated at any location of a bitstream, and is used for access of a bitstream. The I picture is also encoded without reference to other pictures. The I picture is generally compressed using the JPEG format. The I picture can be compressed in real-time using the MPEG format. The I picture

has the lowest compression ratio, when compressed, in the MPEG format. Then, the I picture consists of macroblocks, each of which is an 8*8 block, and is successively subjected to DCT (Discrete Cosine Transformation). During DCT, coefficients are encoded by a DPCM (Differential Pulse Code Modulation) method, which obtains a difference value of the DCT coefficients from successive macroblocks and transforms the difference value using VLC (Variable Length Coding).

[37] A P picture is generated using the previous I picture and previous P picture during encoding/decoding. In most cases, when any one object on successive pictures is moved, image blocks of the object are moved in different directions without change of object shape. In this regard, the P picture is generated by encoding only difference values between a previous picture and a current picture, considering that the difference between the previous picture and the current picture is very small.

[38] A B picture is generated using the previous and current I and P pictures during encoding/decoding. A high compression rate can be obtained through using the B picture. A B picture has a difference value between the previous I picture or P picture and an I picture or P picture following the B picture.

[39] FIG. 5 is a block diagram describing a conventional bit-rate control method used in transcoding.

[40] A target bit-allocation unit 520 receives X_I, X_P, and X_B values for each picture output from an MPEG decoder 510, calculates the target bit values T_I,

T_P, and T_B for each picture, and transfers these values to a bit-rate control unit. The X_I, X_P, and X_B values represent complexity of an I picture, complexity of a P picture, and complexity of a B picture, respectively. The T_I, T_P, and T_B values represent the number of target bits for the I picture, P picture, and B picture, respectively. The T_I, T_P, and T_B values are calculated using Equations 2 below. A bit-rate control unit 530 receives these values, calculates quantization values thereof, and transfers the quantization values to a video encoding unit 540. The video encoding unit 540 uses the quantization values to perform quantization and encoding, and then transfers the encoded bitstream to an output buffer 550.

$$T_I = \frac{X_I}{X_I + \sum_{i=1}^{N_P} X_P + \sum_{j=1}^{N_B} X_B} \times T_{GOP}$$

$$T_P = \frac{X_P}{\sum_{i=1}^{N_P} X_P + \sum_{j=1}^{N_B} X_B} \times (T_{GOP} - S)$$

$$T_B = \frac{X_B}{\sum_{i=1}^{N_P} X_P + \sum_{j=1}^{N_B} X_B} \times (T_{GOP} - S) \qquad \text{..... (2)}$$

[41] T_{GOP} represents the number of bits allocated to each GOP according to the number of target bits. Also, S represents the number of bits for all pictures generated from a first picture to a current picture in one GOP. N_P and N_B represent the numbers of P and B pictures in the GOP currently remaining to

be encoded, respectively. Accordingly, each denominator in the above Equations is the sum of complexities for each of the pictures in one GOP remaining to be encoded. $T_{GOP} - S$ represents the number of bits currently in one GOP remaining.

[42] A decoded picture and a picture to be encoded represent images at a same time. If a complexity value X of the input bitstream is used as a complexity value of the output bitstream, bit-rates can not be efficiently controlled. This is because bit-rate of the input bitstream and bit-rate of the output bitstream are different from each other. Also, when the image size is reduced in transcoding, it becomes more difficult to match the complexity value X of the input bitstream with the complexity value of the output bitstream.

[43] FIG. 6 is a block diagram showing the construction of a transcoding apparatus, according to the present invention.

[44] The transcoding apparatus includes an MPEG decoder 610, a complexity estimator 620, a target bit-allocation unit 630, a bit-rate control unit 640, a video encoding unit 650, and an output buffer 660.

[45] The MPEG decoder 610 receives a compressed bitstream, according to the MPEG standard and performs decoding thereof.

[46] The complexity estimator 620 estimates complexity for each picture using information decoded by the MPEG decoder 610 and encoded

information at a previous time. The complexity for each picture is calculated using Equation 3 below.

$$\hat{X}_{out,I} = \frac{X'_{out,I}}{X'_{in,I}} \times X_{in,I}$$

$$\hat{X}_{out,P} = \frac{X'_{out,P}}{X'_{in,P}} \times X_{in,P}$$

$$\hat{X}_{out,B} = \frac{X'_{out,B}}{X'_{in,B}} \times X_{in,B} \qquad \text{..... (3)}$$

[47] $\hat{X}_{out}$ denotes the estimated picture complexity of a decoded picture before encoding, and is used to determine the number of target bits. X_{in} denotes the complexity of a decoded current picture, X'_{in} denotes the complexity of a decoded previous picture, and X'_{out} denotes the complexity of a previous picture after encoding.

[48] FIGs. 7A and 7B are graphs showing complexity ratios of encoded previous pictures to decoded previous pictures with respect to picture number according to the MPEG standards, respectively.

[49] FIG. 7A illustrates a complexity ratio of the encoded previous picture to the decoded previous picture when transcoding input video from a bit-rate of 20Mbps to 4Mbps, and FIG. 7B illustrates a complexity ratio of the decoded previous picture to the encoded previous picture when transcoding

input video from a bit-rate of 20Mbps to 2Mbps. With reference to FIGs. 7A and 7B, the complexity ratio of the encoded picture to the decoded picture at the previous time has a constant characteristic over time.

[50] The target bit-allocation unit 630 performs bit-allocation using the calculated complexity of a current picture. That is, complexity of a picture to be currently encoded is calculated through Equation 3 above using the complexities of the decoded previous and current pictures and the complexity of the encoded previous picture. Then, bit-allocation for an I picture is performed using Equation 4 below. Likewise, bit-allocations for P and B pictures are also performed using Equation 5 and Equation 6 below.

$$T_I = \frac{\hat{X}_{out,I}}{\hat{X}_{out,I} + \sum_{i=1}^{N_P} \hat{X}_{out,P}[i] + \sum_{j=1}^{N_B} \hat{X}_{out,B}[j]} \times T_{GOP}$$

$$= \frac{X_{in,I} \times \omega_I}{X_{in,I} \times \omega_I + \sum_{i=1}^{N_P} X_{in,P}[i] \times \omega_p + \sum_{j=1}^{N_B} X_{in,B}[j] \times \omega_B} \times T_{GOP}$$

$$\omega_I = \frac{X'_{out,I}}{X'_{in,I}}, \quad \omega_P = \frac{X'_{out,P}}{X'_{in,P}}, \quad \omega_B = \frac{X'_{out,B}}{X'_{in,B}} \qquad \text{..... (4)}$$

$$T_P = \frac{\hat{X}_{out,P}}{\hat{X}_{out,I} + \sum_{i=1}^{N_P} \hat{X}_{out,P}[i] + \sum_{j=1}^{N_B} \hat{X}_{out,B}[j]} \times T_{GOP}$$

$$= \frac{X_{in,P} \times \omega_P}{X_{in,I} \times \omega_I + \sum_{i=1}^{N_P} X_{in,P}[i] \times \omega_P + \sum_{j=1}^{N_B} X_{in,B}[j] \times \omega_B} \times T_{GOP}$$

$$\omega_I = \frac{X'_{out,I}}{X'_{in,I}}, \ \omega_P = \frac{X'_{out,P}}{X'_{in,P}}, \ \omega_B = \frac{X'_{out,B}}{X'_{in,B}} \qquad \ldots\ldots (5)$$

$$T_B = \frac{\hat{X}_{out,B}}{\hat{X}_{out,I} + \sum_{i=1}^{N_P} \hat{X}_{out,P}[i] + \sum_{j=1}^{N_B} \hat{X}_{out,B}[j]} \times T_{GOP}$$

$$= \frac{X_{in,B} \times \omega_B}{X_{in,I} \times \omega_I + \sum_{i=1}^{N_P} X_{in,P}[i] \times \omega_P + \sum_{j=1}^{N_B} X_{in,B}[j] \times \omega_B} \times T_{GOP}$$

$$\omega_I = \frac{X'_{out,I}}{X'_{in,I}}, \ \omega_P = \frac{X'_{out,P}}{X'_{in,P}}, \ \omega_B = \frac{X'_{out,B}}{X'_{in,B}} \qquad \ldots. (6)$$

[51] The bit-rate control unit 640 controls bit-rate using the bit-allocation information and state information of an output buffer, which outputs the encoded bitstream. The video encoding unit 650 encodes the decoded pictures based on the control information of the bit-rate control unit 640. The output buffer stores the bitstream generated by the video encoding unit 650 and outputs the bitstream according to a desired bit-rate.

[52] FIG. 8 is a flow chart illustrating a transcoding method according to the present invention.

[53] First, the compressed bitstream of a current picture is input and decoded (step S810). The compressed bitstream may be compressed in an MPEG format. Then, the complexity of the decoded current picture is estimated in order to encode the decoded current picture (step S820). That is, complexity of a picture to be currently encoded is calculated using the complexity information of the decoded previous and current pictures and the complexity information of the encoded previous picture. The complexity of the picture is calculated using Equation 3 above.

[54] Successively, bit-allocation is performed using the complexity information of the current picture calculated by Equation 3 (step S830). If the calculated complexity of the current picture is large, the number of bits to be allocated to the picture is increased, and if the calculated complexity of the current picture is small, the number of bits to be allocated to the picture is decreased, wherein, the number of bits allocated to the picture is calculated using the above Equation 4. Then, bit-allocation information and state information of an output buffer, which outputs the encoded bitstream, is used for bit-rate control (step S840). The decoded pictures are encoded and output on the basis of the control information of the bit rate control unit (step S850).

[55] FIGs. 9A through 9C are graphs showing image quality variations with respect to frame numbers, comparing a transcoding method according to the present invention to the conventional technique.

[56] FIG. 9A is a graph illustrating image quality variation with respect to frame numbers when transforming from a bit-rate of 20Mbps to a bit-rate of 4Mbps in a "basketball" image according to the MPEG standards. FIG. 9B is a graph illustrating image quality variation with respect to the frame numbers when transforming from a bit-rate of 10Mbps to a bit-rate of 4Mbps in a "flower" image according to the MPEG standards. FIG. 9C is a graph illustrating image quality variation with respect to the frame numbers when transforming from a bit-rate of 10Mbps to a bit-rate of 4Mbps in a "mobile calendar" image according to the MPEG standards. Referring to FIGs. 9A through 9C, an excellent image quality is obtained, when compared with the method disclosed in the above-mentioned U.S. Published Patent Application No. 2002-080877.

[57] According to the present invention, when allocating target bits for bit-rate control during transcoding, efficient picture complexity estimations are possible, by estimating picture complexity using complexity information of decoded pictures at current and previous times, and complexity information of an encoded picture at a previous time. Accordingly, bit-allocation and bit-rate control of a transcoding apparatus are efficiently performed, thereby further improving image quality in the transcoding.

[58] The present invention may be embodied in a general purpose digital computer by running a program from a computer readable medium, including but not limited to storage media such as magnetic storage media (e.g., ROM's,

floppy disks, hard disks, etc.), optically readable media (e.g., CD-ROMs, DVDs, etc.) and carrier waves (e.g., transmissions over the Internet). The present invention may be embodied as a computer readable medium having a computer readable program code unit embodied therein for causing a number of computer systems connected via a network to affect distributed processing.

[59] While the present invention has been particularly shown and described with reference to exemplary embodiments thereof, it will be understood by those of ordinary skill in the art that various changes in form and details may be made therein without departing from the spirit and scope of the present invention as defined by the following claims.